Dawn of Science

23. The Quest for Power

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The practical necessity for developing steam power came from the rapid deforestation in England in the seventeenth century.

The earliest civilisations used human muscle power and animal power in their agricultural and domestic pursuits. The efficiency, which could be achieved in these forms, was necessarily very limited. Soon it was realised that water and wind could be harnessed to provide power. Though windmills and water wheels could be considered technological innovations, the real breakthrough came only with the use of steam. The story of steam forms an interesting chapter in the history of technology.

The theoretical basis for using steam power came from the investigations of Otto Von Guericke (1602–1686) and Robert Boyle (1627–1691). The practical necessity, on the other hand, came from the rapid deforestation of England in the 17th century. The English Navy needed large quantities of wood for ship-building and consequently wood became scarce as a fuel. England, of course, had huge deposits of coal, which could serve as alternative fuel. But the coal-mines used to get repeatedly water-logged rendering them unusable. The usual procedure was to pump out the water by hand or by using horses. This was quite complicated and slow.

It occurred to an English engineer, Thomas Savery (1650–1715), that air pressure could be put to use to pump out water more efficiently. The idea essentially consisted of filling a vessel with steam and then condensing the steam; the vacuum produced inside the vessel would then suck the water up from the mine if a tube were connected between the vessel and the mine. This instrument, which was called the Miner's Friend, was the first practical steam engine. Significant improvements in its design

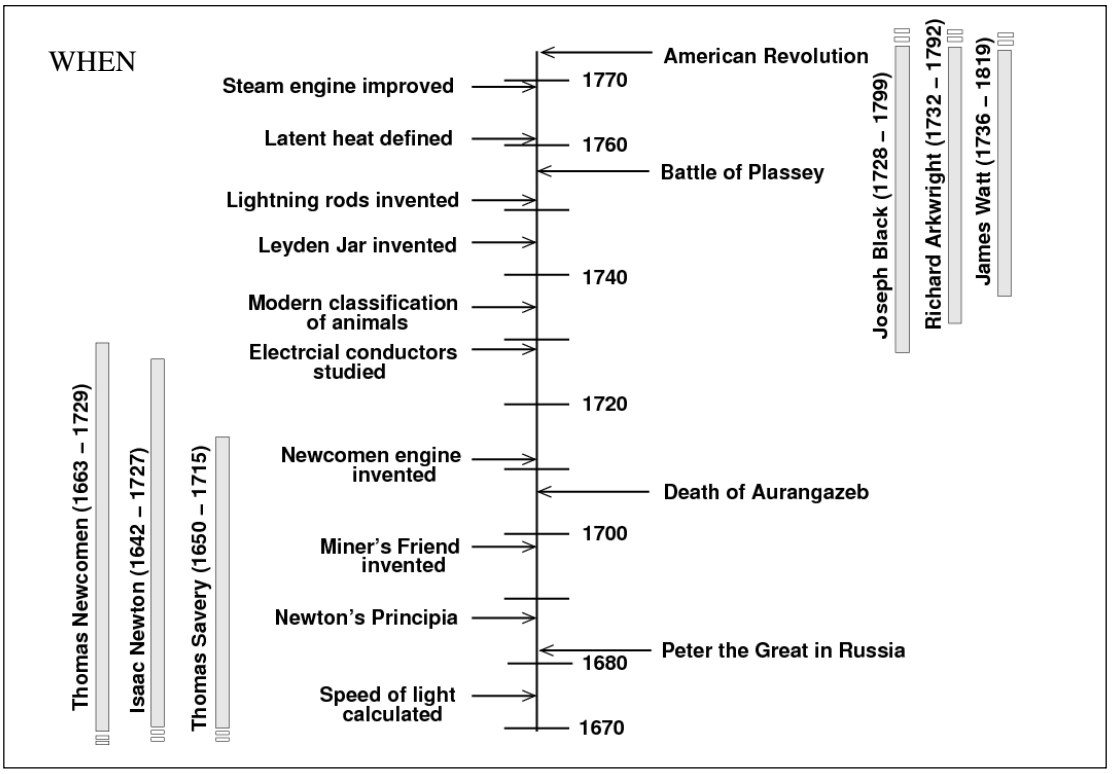


Figure 1.

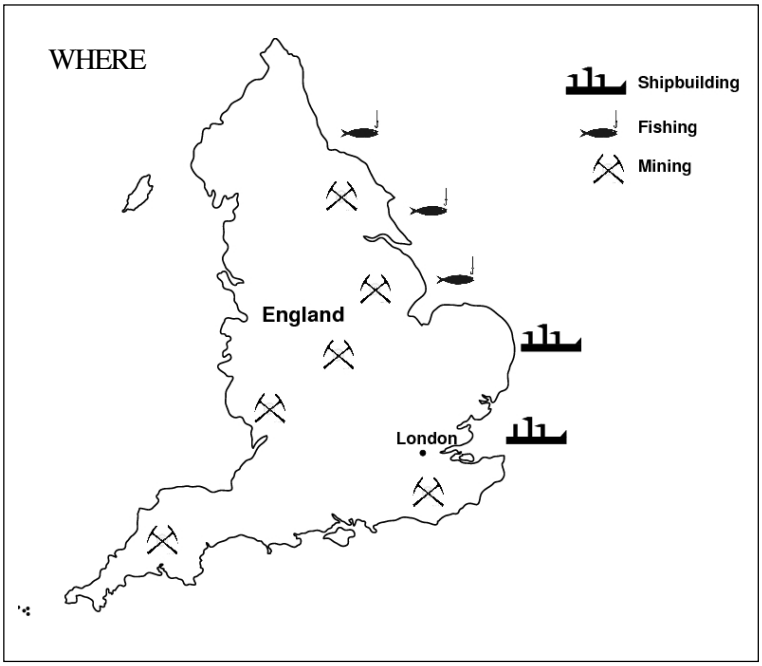


Figure 2.

Figure 3. James Watt.
Courtesy:
http://en.wikipedia.org/wiki/James_Watt

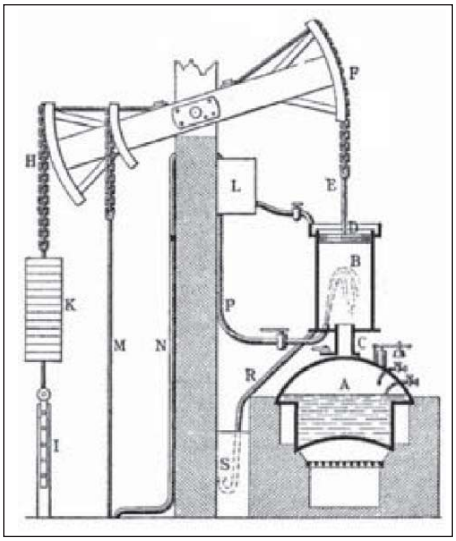
were introduced by Thomas Newcomen (1663–1729), a blacksmith, who made very robust structures and carefully polished pistons. The first machine was set up in Staffordshire in 1712.

Though the Newcomen engine served its purpose, it consumed too much fuel. The next major breakthrough which allowed the economical use of the steam engine came from the Scottish engineer, James Watt[1] (1736–1819). Watt was a sickly child and had an uneventful childhood. In his teens, he spent a year in London as an apprentice in a workshop learning the use of various tools. He had a very good aptitude for engineering. In 1757, he opened a shop at the University of Glasgow which made several mathematical instruments like quadrants, compasses, etc. There he met the Scottish chemist, Joseph Black (1728–1799), and learnt from him certain curious facts about heat. Black had conducted a series of experiments in thermodynamics, which made him realise that the quantity of the heat energy was not the same as the temperature.

[1] See *Resonance,* Vol.14, No.6, 2009.

For instance, when he heated ice, it absorbed the heat energy and melted, though its temperature did not change. Similarly, he noticed that energy supplied to water at its boiling point went into converting it to steam without changing its temperature. These observations implied that there was more heat content in steam at 100 °C compared to boiling water at 100 °C. Black named it 'latent heat' and mentioned these results to James Watt.

Figure 4. The Newcomen steam engine.
Courtesy:
http://en.wikipedia.org/wiki/Steam_power_during_the_Industrial_Revolution



This knowledge was of crucial importance to Watt. In 1764, he was called upon to repair a Newcomen steam engine. In the course of doing so, Watt realised that it was the latent heat that was causing significant wastage of energy in these engines. To condense the steam, it was necessary to cool the vessel containing the steam; but then it had to be filled again with steam for the next cycle of operation. Most of the energy now went into merely heating the chamber back to a high temperature. Thus in every cycle of operation, a

tremendous amount of energy was wasted because the vessel was repeatedly heated and cooled.

Watt hit upon an ingeniously simple solution to this problem. He introduced a second chamber (called 'condenser') into which the steam could be led. It was now possible to keep the first chamber (called 'cylinder') always hot and the second chamber always cold. By 1769, Watt produced a steam engine, which had far greater fuel efficiency than a Newcomen engine. Further, it worked considerably faster since there was no pause between heating and cooling the chambers.

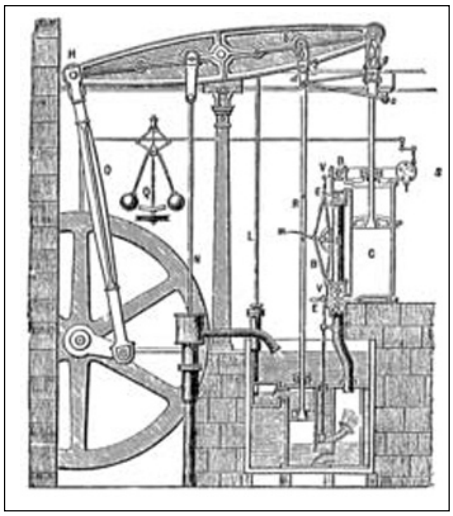


Figure 5. One of the first steam engines based on the double-acting principle, developed by Mathew Boulton and Watt.
Courtesy:
http://en.wikipedia.org/wiki/James_Watt]

In the following years Watt introduced several crucial improvements, making the steam engine truly versatile. For example, he arranged for the steam to enter alternately from two sides of a piston so that useful work could be extracted during both the pushing and pulling motions of the piston. He also devised mechanical attachments, which converted the back-and-forth movements of the piston into a rotary movement of the wheel or to any other form of motion. The steam engine thus became the first modern device, which could serve multiple purposes by using energy that occurred in nature (in the form of fuel) to run virtually any form of machinery. Watt entered into partnership with a businessman and produced steam engines commercially for sale. By 1800, his engines had totally replaced Newcomen engines. And there were over 500 of these working in England.

The consequences of this invention were far-reaching. Steam engines powered by coal could deliver energy constantly at any spot. Manufacturing locations and factories no longer needed to be near streams or waterfalls. Large scale production of commodities became cheap with the availability of unlimited sources of power. Handicrafts became non-viable and the artisan was replaced by the factory worker. Cities grew along with industries, and so did urban life and all the benefits and evils of the factory system. In short, the industrial revolution began with the steam

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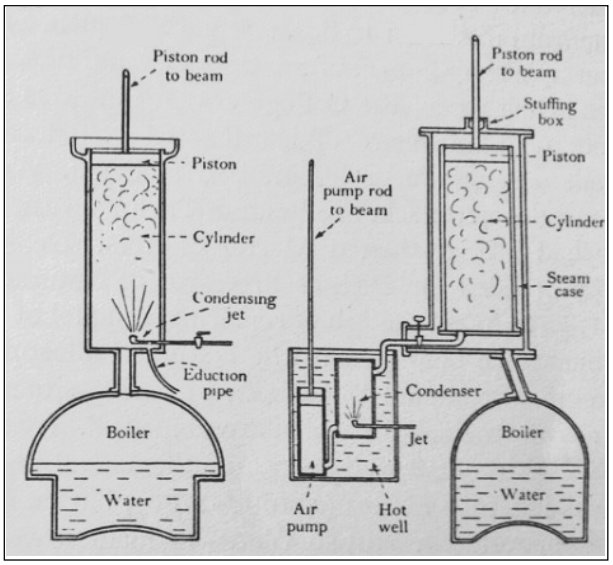

Figure 6. Mechanical arrangements in Newcomen's and Watt's steam engines.
Courtesy: Dickenson [1].

engine. One immediate use of mechanization was in the field of the textile industry, which was of prime importance to England. Richard Arkwright (1732–1792) and others invented machinery which would replace hard work in textile manufacture. They became the first group of 'capitalists'.

James Watt's work was amply recognised in his time. He was elected Fellow of the Royal Society in 1785 and was made a foreign associate of the French Academy of Sciences in 1814. In addition, he earned enough wealth from his royalties. In one of his experiments, Watt noticed that a strong horse could raise a weight of a hundred pounds nearly four feet in about a second. He therefore coined the term 'horsepower', defining it as 550 foot-pounds per second. Today, however, the metric system measures power in the unit 'Watt' in honour of this inventor of the steam engine. One horsepower is 746 Watts.

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Suggested Reading

[1] **Henry Winram Dickinson, *A short history of the steam engine*, Cambridge University Press, 1939.**
[2] **J Meidenbauer (Ed.), *Discoveries and Inventions*, Dumont Monte, 2002.**
[3] **Isaac Asimov, *Asimov's Biographical Encyclopedia of Science and Technology*, Doubleday, 1982.**